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REPORT

SATELLITE BROADCASTING: channel separation requirements for f.m. sound signals and for a f.m. sound signal adjacent to a f.m. television signal

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SATELLITE BROADCASTING: CHANNEL SEPARATION REQUIREMENTS FOR F.M. SOUND SIGNALS AND FOR A F.M. SOUND SIGNAL ADJACENT TO A F.M. TELEVISION SIGNAL

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Summary

This report describes experimental work carried out to determine the frequency separation required between high-deviation f.m. sound signals, and between f.m. sound and f.m. television signals, when they are transmitted on adjacent channels.

A frequency separation of 0·8 MHz is recommended for situations where two f.m. sound services occupy adjacent channels and, where sound and television services occupy alternate channels, a separation of 15 MHz is recommended. The separation required between television signals with sound accompaniment on a separate carrier is also covered and compared with the requirements for television signals which incorporate the accompanying sound signal on a subcarrier. In these cases, the separations recommended are 30 MHz and 29·5 MHz, respectively.

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1. Introduction

When a broadcasting service is planned, it is necessary to know the bandwidth required for the signal transmitted in each broadcasting channel and also the frequency separation needed between channels so that effective use may be made of the band of frequencies available. Satellite broadcasting would involve the use of relatively low-power transmitters (because of the limited power resources of the satellite) and hence would require wideband systems of modulation, such as frequency modulation (f.m.), to obtain a satisfactory signal-to-noise ratio.

This paper describes experimental work carried out at the BBC Research Department on adjacent-channel interference between high-deviation f.m. sound signals, and between a f.m. sound signal and a f.m. television signal, in order to determine the channel spacing requirements for these wideband transmissions.

2. Experimental arrangement

2.1. System parameters

It is assumed that a high-deviation f.m. sound broadcasting system suitable for use with a satellite transmitter would employ a deviation of ±300 kHz peak and that the transmitter output power would be one fortieth of that used by a satellite f.m. television transmitter.

Some of the tests described involve interference between f.m. television signals and f.m. sound signals. The modulation standards of f.m. television signals used in the tests conformed to recommendations made by Sub-Group K3 of the European Broadcasting Union, with a deviation of 13 MHz peak-to-peak for a 1 volt video signal after CCIR pre-emphasis plus, when the accompanying sound signal is transmitted on a subcarrier, a deviation of ±2·8 MHz peak by the f.m. sound subcarrier at or near 6 MHz. The peak deviation of the sound subcarrier by programme was ±50 kHz. All television signals were pre-emphasised in accordance with the CCIR Recommendations,[1] as the use of pre-emphasis has been found to give a significant reduction in differential gain and phase distortion.[2]

Sound signals, for both separate-carrier and subcarrier transmission, were pre-emphasised with the European standard time constant of 50 μs.

2.2. Equipment

Fig. 1 shows a block schematic diagram of the equipment used for the tests involving a wanted f.m. sound signal with an interfering f.m. sound signal in the adjacent channel. The sound receiver filter consisted of four tuned circuits arranged as two coupled pairs and incorporated in a 70 MHz amplifier. The receiver bandwidth was 0·6 MHz to the −3 dB points, centred on 70 MHz, and the amplifier provided sufficient gain to overcome the losses in the tuned circuits and enable the limiter stages to operate satisfactorily. Limiting, demodulation and de-emphasis were provided by a commercial modulation meter, and this instrument was also used to set up the deviation of the signal sources. A spectrum analyser was used to check the deviations and set up the output levels of the sources.

For tests where the wanted sound signal was subjected to interference from a f.m. television signal, the interfering sound signal generator was replaced by a f.m. television signal generator. When tests were conducted with a television signal as the wanted programme with a f.m. sound signal interfering, the wanted signal was provided by a 70 MHz f.m. television signal generator and the i.f. amplifier, filter, limiter and discriminator were replaced by units designed for f.m. television signals. The f.m. modulator used for the television signals produced a deviation of the carrier to a higher frequency for the synchronising pulses of the video waveform.

3. Description of tests

When a f.m. sound signal was the wanted programme, the tests consisted of objective measurements made with a BBC-modified Niese meter[3] (giving r.m.s. readings for con-

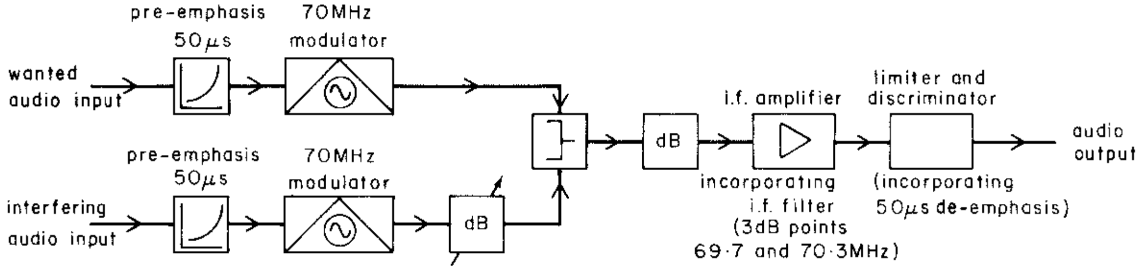

Fig. 1 - Experimental arrangement

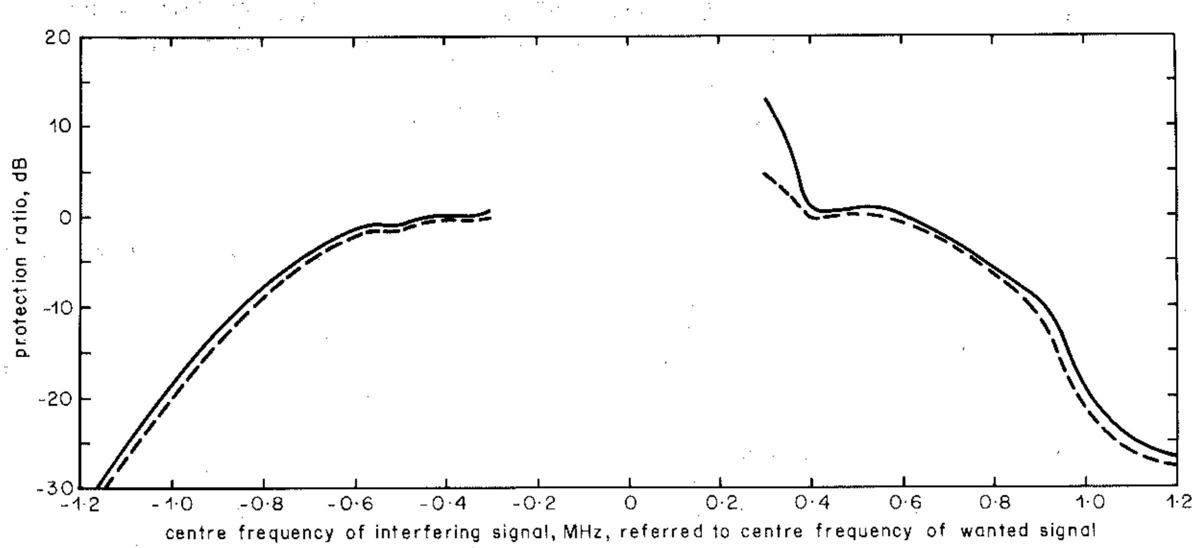

Fig. 2 - Protection ratio as a function of frequency separation of wanted and interfering high-deviation f.m. sound signals
——————— Protection ratio required for 60 dB (weighted) signal-to-noise ratio
- - - - - - - - - Protection ratio required for 50 dB (weighted) signal-to-noise ratio

tinuous noise) using the CCIR weighting network.[4] This combination of measuring equipment has been found to give good agreement with subjective data on the impairment characteristics of different types of noise and disturbance in sound circuits and was chosen for a series of objective tests as a suitable alternative to the relatively time-consuming subjective tests.

Subjective tests were used when a f.m. television signal was the wanted programme. Owing to the limited time available, only two viewers were used to judge each test. These viewers, who were technical personnel, graded the pictures according to a 6-point impairment scale.*

It has been assumed in the present work that the worst adjacent-channel protection ratio that will occur when both the wanted and interfering signals are of the same type, either television or radio, is −6 dB. Furthermore, with a ratio of 16 dB between the power outputs of satellite vision and sound transmitters, as mentioned in Section 2.1, the minimum protection ratio given to a television signal against a sound transmission in the adjacent channel will be 10 dB. Conversely, the minimum protection ratio given to a sound signal against a television transmission in the adjacent-channel will be −22 dB.

3.1. Tests with a high-deviation f.m. sound signal as the wanted programme

Measurements were made, using the modified Niese meter, to determine the relationship between protection ratio and frequency separation when two f.m. sound signals are in adjacent channels. The reference modulation of the wanted signal for these measurements was ±300 kHz deviation at 1 kHz. The interfering signal was deviated ±300 kHz at 1 kHz throughout this test. Protection ratios were determined for weighted signal-to-noise ratios of 50 dB and 60 dB, measured at the output of the sound receiver, and the results of measurements made for frequency spacings greater than ±300 kHz are presented as graphs in Fig. 2. It is anticipated that a weighted signal-to-noise ratio of 60 dB will be deemed necessary for a satisfactory sound broadcasting service although 50 dB may be acceptable for a television sound channel.

Results were obtained for the whole range of frequency spacings between zero and ±1·2 MHz but it is suggested that those for frequency spacings between about ±300 kHz, are of doubtful accuracy. The reason for this is that the modulation applied to the interfering signal, i.e. ±300 kHz deviation at 1 kHz, while representing a most demanding condition for adjacent-channel interference, probably gives protection ratios that are inadequate for close channel spacings. Further work with other levels of modulation on the interfering signal would be required to determine the co- and close-channel protection with greater accuracy.

Fig. 3 shows graphs of the results obtained when a f.m. television signal with a 6 MHz sound subcarrier interferes with the wanted sound signal, and Fig. 4 shows the results when the interfering signal is f.m. television without a sound subcarrier. The interfering video signal was 100% colour bars, and the graphs of results exhibit a number of maxima and minima as the spectrum of the television signal is 'scanned' by the sound receiver, with its relatively narrow bandwidth, at different frequency separations. The precise shape of the graphs in the region where the passband of the television signal overlaps that of the wanted sound signal depends upon the nature of the video modulation.

* The 6-point impairment scale used was that given in CCIR Report 405-1 (New Delhi, 1970) and is as follows:

1. Imperceptible
2. Just perceptible
3. Definitely perceptible, but not disturbing.
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

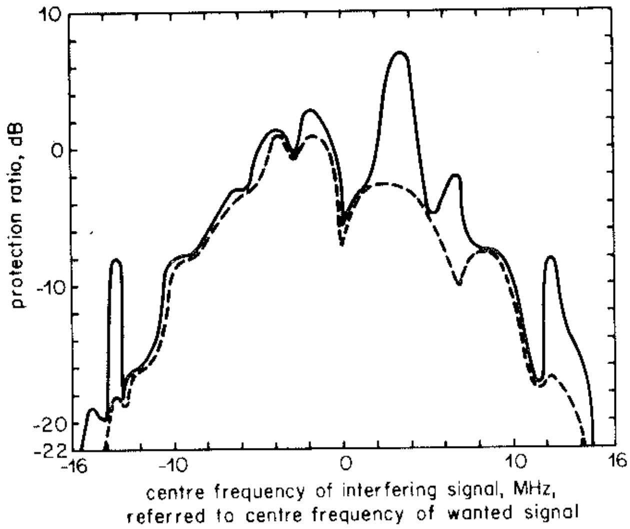

Fig. 3 - Protection ratio as a function of frequency separation when the wanted signal is high-deviation f.m. sound and the interfering signal is f.m. television (with a 6 MHz sound subcarrier)

——— Protection ratio required for 60 dB (weighted) signal-to-noise ratio

– – – – Protection ratio required for 50 dB (weighted) signal-to noise ratio

3.2. Tests with a f.m. television signal as the wanted programme

Subjective tests were used to determine the protection ratio required to give a grade 2 picture from a f.m. television signal without sound subcarrier when the interfering signal is f.m. sound with full modulation at 1 kHz. The graph of Fig. 5 shows the results obtained with a receiver bandwidth of 22 MHz. Tests were also conducted with a receiver bandwidth of 27·5 MHz; the results of these latter

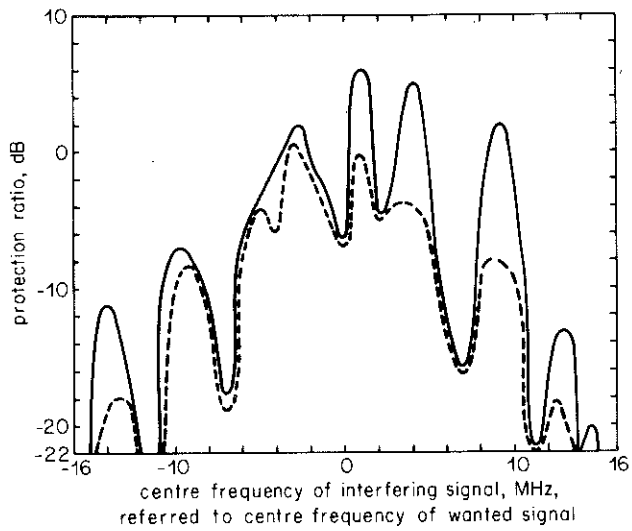

Fig. 4 - Protection ratio as a function of frequency separation when the wanted signal is high-deviation f.m. sound and the interfering signal is f.m. television (without sound)

——— Protection ratio required for 60 dB (weighted) signal-to-noise ratio

– – – – Protection ratio required for 50 dB (weighted) signal-to-noise ratio

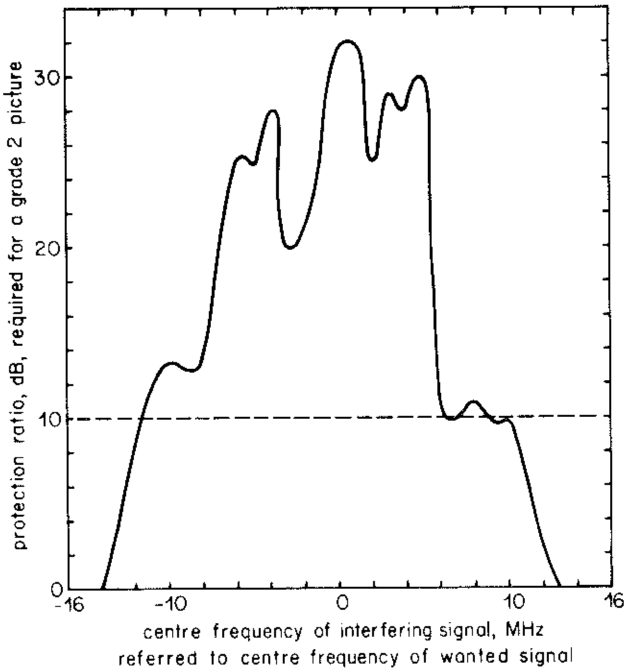

Fig. 5 - Protection ratio as a function of frequency separation when the wanted signal is f.m. television (without sound) and the interfering signal is high-deviation f.m. sound. The receiver bandwidth is 22 MHz

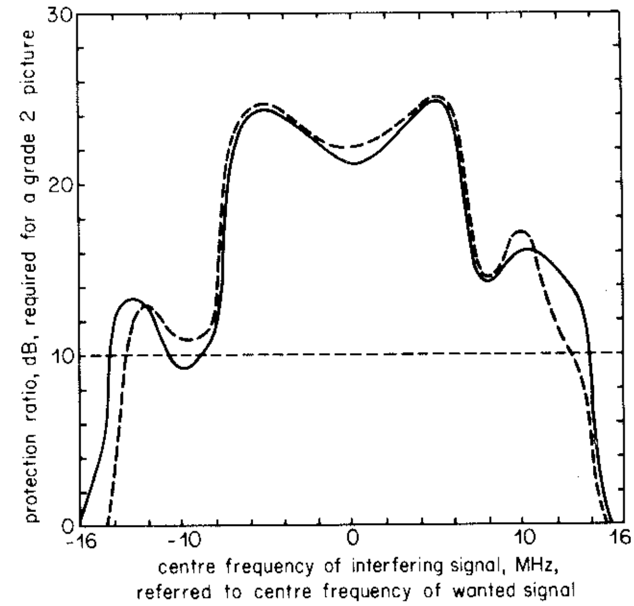

Fig. 6 - Protection ratio as a function of frequency separation when the wanted signal is f.m. television (with a 6 MHz sound subcarrier) and the interfering signal is high-deviation f.m. sound. The receiver bandwidth is 27·5 MHz

——— Result obtained when the interfering sound signal is 100% modulated by a 1 kHz tone

– – – – Result obtained when the interfering sound signal is unmodulated

tests have not been included as they are virtually the same as those obtained for a wanted television signal with subcarrier sound in the same bandwidth (full-line graph of Fig. 6).

Another set of subjective tests was made with a f.m. television signal incorporating a 6 MHz sound subcarrier as the wanted signal and a f.m. sound signal interfering, and the results are shown in the graphs of Fig. 6. The receiver bandwidth used for these tests was 27·5 MHz. No measurements were made of interference in the sound channel of the combined signal in this case as it had already been established[5] that the picture quality assessment is the more sensitive test of adjacent-channel interference.

4. Discussion of results

4.1. Interference between two sound signals

In a situation where two high-deviation f.m. sound transmissions are on adjacent channels and the unwanted signal is at a level of +6 dB relative to the wanted signal, a frequency separation of 0·8 MHz is required for a weighted signal-to-noise ratio of 60 dB at the receiver output. The graphs of Fig. 2, from which this result is obtained, exhibit a degree of asymmetry and this is probably caused by the receiver filter. Spectrum analyser checks on the f.m. sound signal spectra showed them to be very nearly symmetrical.

The two graphs in Fig. 2 are very close together over most of the range for which they were plotted. This means that a relatively small change in the protection ratio or frequency separation produces a relatively large change in the output signal-to-noise ratio. It is therefore most important that the frequency separation provided should make sufficient allowance for the worst possible protection ratio and for a reasonable variation of receiver selectivity.

4.2. Interference between television and sound signals

There are two situations which can arise where sound and television broadcasts occupy adjacent channels. One such situation occurs when the sound accompaniment to the television programme is transmitted as a separate f.m. carrier in the adjacent channel, the other is when television and sound broadcasting services are planned in the same satellite broadcasting band.

When f.m. sound and f.m. television signals occupy adjacent channels, the frequency separation needed is dictated by the requirements of the sound signal. The results for a television signal interfering with sound (Figs. 3 and 4) show that the sound signal needs a separation of 15 MHz if the television signal has no sound subcarrier or 15·5 MHz if there is a sound subcarrier. Both of these figures for frequency separation are for a protection ratio of −22 dB.

In the reciprocal case, when a sound transmission interferes with television, a separation of 10 MHz or 12 MHz is needed for sound in the upper or lower adjacent channel respectively of a television signal without a sound subcarrier if the television receiver has a bandwidth of 22 MHz.

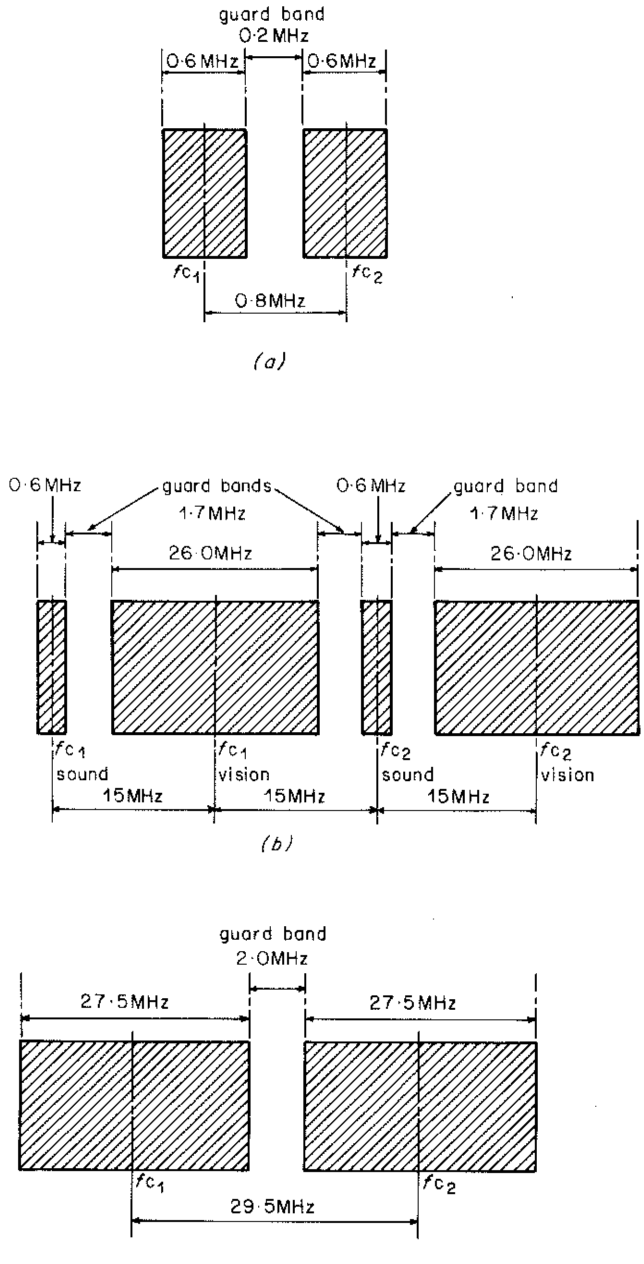

Fig. 7 - Diagrammatic representation of channel separation requirements for the three principal cases

(*a*) Two sound signals in adjacent channels

(*b*) Sound signals adjacent to television signals (without sound subcarriers). This example illustrates the adjacent channel requirements for television signals with sound on a separate carrier.

(*c*) Two television signals (with 6 MHz sound subcarriers) in adjacent channels.

An interfering signal higher in frequency than the wanted television signal affects the synchronising pulses rather than the picture components of the television waveform (see Section 2.2). Thus it is possible to tolerate an interfering signal at a closer spacing on the higher-frequency side of the wanted television signal.

If the receiver bandwidth is increased to 27·5 MHz, a

separation of 14 MHz or 15 MHz is required between the wanted television signal and an interfering sound signal in the upper or lower adjacent channel respectively. These results apply whether the television signal incorporates a sound subcarrier or not, and are valid for a protection ratio of +10 dB.

5. Conclusions

F.M. sound transmissions employing a peak deviation of ±0·3 MHz need a frequency separation of at least 0·8 MHz between channels. For the reasons stated in the discussion of results, it is thought that a rather greater separation than this may be desirable.in practice.

When a f.m. sound transmission occupies the channel adjacent to a f.m. television transmission with no sound subcarrier, a frequency separation of 15 MHz is needed. Thus a f.m. television signal with its sound accompaniment on a separate f.m. carrier requires the sound carrier to be spaced 15 MHz from the vision carrier rest frequency and 15 MHz from the vision carrier rest frequency of a television transmission in the adjacent channel. Since this requirement must be met to protect the sound channels, it should be noted that no reduction of channel spacing would result if the receiver vision i.f. bandwidth were reduced, assuming a vision/sound transmitter power ratio of 16 dB. Thus a spacing of 30 MHz between channels is required for a system using separate sound carriers. Earlier work has shown that a spacing of 29·5 MHz between channels is necessary when the sound signal accompanying the television programme is incorporated with the vision signal on a 6 MHz subcarrier.[5]

Fig. 7 is a diagrammatic representation of these conclusions.

When a f.m. sound transmission occupies the channel adjacent to a f.m. television signal which incorporates the sound accompaniment on a 6 MHz subcarrier, a frequency separation of 15·5 MHz is required between the sound and television signal centre frequencies. This situation would arise if the satellite broadcasting band were to be shared by both television and sound radio services.

6. References

1. CCIR Recommendation 405-1, XIIth Plenary Assembly (New Delhi, 1970), Vol. IV, Part I, p. 148.

2. GILCHRIST, N.H.C. 1973. Satellite broadcasting: bandwidth requirements for f.m. television signals. BBC Research Department Report No. 1973/19.

3. GEDDES, W.K.E. 1968. The assessment of noise in audio-frequency circuits. BBC Research Department Report No. EL-17, Serial No. 1968/8. See CCIR Document 10/175 (Period 1970 – 1974) also issued as CMTT/141.

4. CCIR Recommendation 468, XIIth Plenary Assembly (New Delhi, 1970), Vol. V, Part I, p. 227.

5. GILCHRIST, N.H.C. 1974. Satellite broadcasting: channel separation requirements for f.m. television signals. BBC Research Department Report No. 1974/20.

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